# Chapter 8E: Exotic Species In the EPA

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## INTRODUCTION

Invasive exotic species of animals and plants have become a serious global environmental problem (IUCN, 1999). A recent Cornell University study found that invasive species of plants, mammals, birds, amphibians, reptiles, fish, arthropods, and mollusks cost the United States alone more than $100 billion annually (Pimentel, 2000). Such costs will inevitably continue to increase, especially if efforts to control these invasions are scattered. Planning, resources and actions must be effectively integrated to turn back the overwhelming spread of numerous invasive species.

Florida is listed along with Hawaii, California, and now Louisiana as one of the states with the highest number of non-indigenous species, and South Florida is home to more introduced animals than any other region in the United States. With an estimated 26 percent of all resident mammals, birds, reptiles, amphibians and fish not native to the region, South Florida has one of the largest non-indigenous faunal communities in the world (Gore, 1976; Ewel, 1986; OTA, 1993; McCann, et al., 1996; Shafland, 1996a; Simberloff, 1996; Corn et al., 1999). Thirty years ago a Smithsonian publication described tropical Florida as a “biological cesspool of introduced life” (Lachner et al., 1970).

## INVASIVE SPECIES AND EVERGLADES RESTORATION

Control of exotic invasive species is a far-reaching issue. The importance of this issue in the Everglades Protection Area (EPA) is demonstrated by the large number of plans, reports, statements and papers written on the topic of non-native species by numerous committees, state and federal agencies, public and private universities, state and federal task forces, and various other organizations. Most of the plans, reports, statements and papers support an “all-taxa” approach, and the general consensus of these parties is that control and management of non-indigenous species is a critical component of ecosystem restoration in South Florida.

The topic of invasive species has been identified as an issue since the beginning of the Everglades restoration initiative. Several organized efforts and mandates have highlighted the problems associated with exotic species in the Everglades region. Control and management of invasive exotics are priorities established by the South Florida Ecosystem Restoration Task Force (SFERTF) in 1993. One of the tasks identified in the 1993 charter for the former management subgroup (December 16, 1993) was to develop a restoration strategy that addressed the spread of invasive exotic plants and animals. The U.S. Fish and Wildlife Service (USFWS) was designated as lead agency for this strategy and submitted a brief report (Carroll, 1994). This report highlighted some of the following issues: (1) A limited number of species are designated as "nuisance" species and can be prohibited by law; (2) Current screening processes are deficient; (3) Responsibilities remain vague; (4) There is a general lack of awareness and knowledge of the harmful impacts of invasive species; and (5) There is an urgent need for statewide coordination and cooperation to eliminate exotics. The greatest obstacles, identified in this report, to combating non-indigenous species were a lack of both sufficient funding and manpower to stay ahead of potential problems.

The first annual report of the South Florida Ecosystem Restoration Working Group (SFERWG) in 1994 addressed all non-indigenous species of plants and animals in the region. The overall objectives stated were: (1) to halt or reverse the spread of invasive species already widespread in the environment (2) eradicate invasive species that are still locally contained, and (3) prevent the introduction of new invasive species to the South Florida environment. The Everglades Forever Act (EFA) of 1994 requires the South Florida Water Management District (SFWMD or District) to establish a program to monitor invasive species populations and coordinate with other federal, state, and local governmental agencies to manage exotic pest plants, with an emphasis in the Everglades Protection Area (EPA).

The Scientific Information Needs Report (SSG, 1996) of the SFERTF contains a region-wide chapter on harmful non-indigenous species. One of the overall regional science objectives for the restoration is to develop control methods on exotic invasives at entry, distribution, and landscape levels. Two specific objectives for stopping the spread of non-indigenous species are to halt and reverse the spread of invasive naturalized exotics and also prevent invasions by new exotic species. Major issues facing South Florida are inadequate funding for scientific investigations to develop effective controls, lack of funding to apply control methods to problem species, and delays and a lack of consistency in responses to new problems. Most resources on non-indigenous animals have been focused on agricultural pests, with little investigation of species that threaten natural areas. Particular needs include the implementation of studies to develop control technology; basic biological and ecological studies to improve understanding of invasive exotic species (e.g., how will water management alterations affect non-indigenous plants and animals; identification of the principal controls on expansion of a species; the impacts of invasive species on native species and ecosystems; identification of what makes a natural area susceptible to invasion; and necessary screening and risk assessment technology that would help identify and focus on the greatest potential problems. Overall, the major issue is the lack of meaningful information concerning the effect of non-indigenous species on South Florida.

The Comprehensive Review Study Final Feasibility Report and Programmatic Environmental Impact Study (USACE and SFWMD, 1999) addresses the presence of exotic animals as one of several factors that preclude any serious consideration of achieving true restoration of the natural system, that is, one in which exotic species are not present. The report discusses how removal of canals and levees, which act as deepwater refugia for exotic fish and conduits into interior marshes for other species, is expected to help control exotic species by slowing their continued movement into relatively pristine areas. On the other hand, restoration of lower salinity levels in Florida Bay may result in increases of reproductively viable populations of exotic fishes, such as the Mayan cichlid, in the freshwater transition zone, and this potential problem must be addressed during detailed design.

The U.S. Department of the Interior's (DOI's) Fish and Wildlife Coordination Act Report (FGFWFC, 1999) for the Comprehensive Everglades Restoration Plan (CERP) also considers control and management of non-indigenous species a critical aspect of ecosystem restoration in South Florida. The report discusses the effects of the present canal and levee system, as well as that of the preferred alternative of this system, on the distribution of non-indigenous animals.

Some components of the CERP involve construction of canals and reservoirs, which could provide additional conduits from points of introduction into the Everglades for species such as fish, amphibians, and snails; other components involve removal or partial removal of canals, which should reduce the spread of exotic fishes. Removal of levees, which act as artificial terrestrial corridors into the wetland landscape, should reduce the spread of certain species, such as the fire ant. The DOI recommended establishment of an Exotic Animal Task Team to work on the issue during detailed planning for removal of existing structures or construction of new facilities as part of CERP. In relation to planned water preserve areas and flow-ways, DOI recommended that an aggressive plan be developed for the perpetual removal of invasive exotics, both plants and animals. DOI also recommended that existing control measures be accelerated, more effective techniques be developed, and regulations be revised and better enforced to prevent additional introductions of exotic species (FGFWFC, 1999). The U.S. Army Corps of Engineers and the District (USACE and SFWMD, 1999) responded in CERP that this recommendation [team] should be presented to the South Florida Ecosystem Restoration Task Force.

Several other plans and reports also include exotic invasive species. The Coordination Act Reports (FGFWFC, 1999) from the Florida Game and Fresh Water Fish Commission (now the Florida Fish and Wildlife Conservation Commission) emphasize that the extent of the canal system's role in the spread of exotic fishes into natural marshes, as opposed to the fish remaining primarily in the disturbed areas, is debatable. The draft report, *A New Look at Agriculture in Florida* (Evans, 1999), discusses the introduction of exotic pests and diseases as a serious obstacle to sustainable agriculture and the importance of exclusion and control strategies. The South Florida Multi-Species Recovery Plan (USFWS, 1999a) identifies exotic animal control as a restoration need for two-thirds of the ecological communities and the individual species covered in the plan. In addition, the South Florida Regional Planning Council's 1991 and 1995 regional plans for South Florida list the removal of exotic plants and animals and discouragement of introductions of new exotics as regional policies (SFRPC 1991, 1995).

The Florida Department of Environmental Protection (FDEP) formed an Invasive Species Working Group (ISWG) in July 2001. Representatives from 13 state agencies and/or divisions and one state university comprise the ISWG. Florida Gov. Jeb Bush charged this group with developing a comprehensive invasive species plan for state agencies. The plan is in the final phases of development, and the group will begin implementation once the governor accepts it.

On a national level, the President's Executive Order on Invasive Species (Executive Order 13112) recognized the threats posed by invasive species and authorized a national invasive species council, which, among its other duties, prepared a national management plan for invasive species. This plan was finalized and released on January 18, 2001. Implementation of the plan is ongoing through the National Invasive Species Council, chaired by the secretaries of Agriculture, Commerce, and the Interior.

## NON-INDIGENOUS PLANT SPECIES

The South Florida Ecosystem Restoration Task Force and Working Group identified non-indigenous plants as a priority. As a result, the Noxious Exotic Weed Task Team (NEWTT) was established in 1997. NEWTT is a direct working team of the South Florida Ecosystem Restoration Task Force and Working Group and has two main directives. First is the development of an assessment to characterize the current problems with invasive exotic plants in Southern Florida and identify the highest priority invasive species for control. The second directive calls for the development of a comprehensive interagency strategy for elimination or control of the highest priority species, and management to control and minimize the spread of other pest plant species.

The task team is comprised of federal, state and local government agencies. To comply with the Federal Advisory Committee Act and (FACA) Florida's "sunshine laws," all NEWTT meetings are open to the public. While non-governmental organizations (NGOs) are not an official part of NEWTT, the Florida Exotic Pest Plant Council (FLEPPC) provides advice and peer review to the task team.

NEWTT has been charged with developing a comprehensive strategic plan covering the issues and problems of exotic pest plants in Florida, with programmatic and management focus on the Everglades. However, a statewide perspective has been used in developing this strategic plan, because any plan that addresses the issues of exotic pest plants cannot do so in a fragmented geographic or political framework. Federal, state and local governmental policies affect, interact, and sometimes contradict one another and must be addressed synthetically. In addition, the issues and experiences learned regionally (regarding control-method development, research results, public education, technology transfer, policy, regulation, and funding) affect all agencies and programs throughout the state. In turn, national-level issues related to exotic pest plants affect state and local policies and programs.

## NON-INDIGENOUS ANIMAL SPECIES

The effort to address exotic animals in the Everglades has lagged behind that of invasive plants. While it is relatively easy to determine the extent to which non-indigenous plants invade natural areas, the impact of non-indigenous animals on native communities and on those species with which they directly compete is often much less obvious (Schmitz and Brown, 1994). Several reports have highlighted this difficulty.

- The Multispecies Recovery Plan (USFWS, 1999) states:

> "It is probably safe to say that the most severe exotic species threats to the South Florida Ecosystem come from plants, rather than animals. Therefore, the emphasis on exotics in Florida has been on flora, rather than fauna."

- The Scientific Information Needs report (SSG, 1996) stated the problem this way:

> "The role of nonindigenous animals in South Florida natural areas is so poorly documented that it is difficult to design and mount an effective effort to control those that are harmful to native plant and animal communities."

- In the book *Everglades, the Ecosystem and its Restoration,* Robertson and Frederick (1994) bluntly state:

> "Although biologists were quick to anticipate the developing problem, their concerns and pleas for regulation have been thoroughly overrun by events…Any present attempt to assess the overall threat posed by nonnative animals to the integrity of the Everglades ecosystem seems futile…In addition, thought may tend to become paralyzed by the obvious, perhaps insurmountable, difficulty of effective countermeasures."

In spite of the daunting conclusions above, the SFERTF Working Group has been gathering available information as a basis for an assessment of the problem. In February 1998, the working group established an ad hoc interagency team to focus on South Florida and evaluate the status of non-indigenous animals in all habitats (freshwater, marine, and terrestrial), describe efforts underway to deal with them, and identify agency needs and problems (Goodyear, 2000).

Non-native animal species of concern include insects, marine and freshwater fish and invertebrates, reptiles and amphibians, mammals, and birds. Species currently held to be of the greatest concern include: feral pigs (*Sus scrofa*); Norway and black rats (*Rattus norvegicus* and *R. rattus*); nine-banded armadillo (*Dasypus novemcinctus*); European starling (*Sturnus vulgaris*); brown caiman (*Caiman crocodilus*); Tokay gecko (*Gecko gecko*); spinytail iguanas (*Ctenosaura pectinata*, *C. similis*); Cuban knight anole (*Anolis equestis*); brown anole (*Anolis sagrei*); Boa constrictor (*Boa constrictor*); Burmese python (*Python molurus*); Cuban treefrog (*Osteopilus septentrionalis*); Asian swamp eel (*Monopterus albus*); bromeliad weevil (*Metamasius callizona*); Diaprepes weevil (*Diaprepes abbreviatus*); brown citrus aphid (*Toxopotera citricida*); red fire ant (*Solenopsis invicta*); Pacific whiteleg shrimp (*Liptopinaeus vannamei*); zebra mussel (*Dresseina polymorpha*); red-rimmed melania aquatic snail (*Melanoides tuberculata*); and banded tree snail (*Orthalicus floridensis*).

The SFERTF is establishing a Noxious Exotic Animal Task Team (NEATT). This group will convene and develop a non-native animal report to provide a broad picture of the status of non-indigenous animal species in South Florida. The report will focus on the agencies, along with their respective departments, that are represented on the working group. This report is to be used as a basis for the working group to evaluate members' priorities relative to non-indigenous animals and to determine if and how the group might assist the work of individual agencies, enhance interagency collaboration, and integrate South Florida efforts into state, regional, or national programs.

# MANAGEMENT EFFORTS

The District has been closely coordinating all vegetation management efforts with other agencies within the Everglades Protection Area since 1990. This close coordination has resulted in detailed species-based management plans (Melaleuca Management Plan, Brazilian Pepper Management Plan, Lygodium Management Plan) and a maximization of all available management resources. In addition, the District has been required to get permits from the Florida Department of Environmental Protection (FDEP) for all vegetation management activities in public waters since 1979. The permit process has helped to bring peer review and consistency to management approaches statewide. Within the Everglades Protection Area, floating aquatic plant control in canals has been coordinated with the U.S. Fish and Wildlife Service and Everglades National Park since the early 1970s, specifically as it relates to water hyacinth and water lettuce spraying and/or harvesting in and around the S-10 and S-12 structures and within the L-7, L-39, L-40 and the L-29 canals. Currently, the District does not have dedicated staff or funding to coordinate efforts and control non-indigenous animals within the Everglades Protection Area.

## INVASIVE PLANT MANAGEMENT TOOLS

Many different techniques are used to control exotic invasive plants within the Everglades Protection Area. Biological controls, herbicides, manual and mechanical controls, and cultural practices, such as prescribed burning and water-level manipulation, are used separately or in conjunction to slow the spread of exotics. The following section highlights more detailed descriptions of each of these methods. Specific species-level controls are discussed in the "priority species" section below.

### Biological Control

Plants are often prevented from becoming serious weeds in their native range by a complex assortment of insects and other herbivorous organisms. When a plant is brought into the United States, the associated pests are thoroughly screened by government regulations on plant pest importation. Favorable growing conditions and the absence of these associated pest species have allowed some plants to become serious weeds outside their native range.

"Classical" biological control seeks to locate such insects and import host-specific species to attack and control the plant in regions where it has become a weed. The "classical" approach has a proven safety record (none of the approximately 300 insect species imported specifically for this purpose have ever become pests themselves) and has been effective in controlling almost 50 species of weeds.

The following performance steps are those of a classical biological control investigation:

1. Identify the target pest and prepare a report outlining problem conflicts, the potential for a successful program, etc.
2. Survey and identify the pest's native range for a list of herbivores that attack the pest plant.
3. Identify the best potential biocontrol agents based on field observations, preliminary lab tests, and information from local scientists.

4. Conduct preliminary host-range tests on the most promising candidate in the pest's native country to obtain permission to import the candidate to U.S. quarantine.
5. Complete host-range tests in U.S. quarantine to ensure safety of the organism relative to local native plants, agricultural crops, and ornamentals.
6. Petition the United States Department of Agriculture (USDA) Technical Advisory Group for permission to release the organism into the United States. Also, obtain permission from necessary state agencies.
7. Culture-approved agents to acquire sufficient numbers for release at field sites; test release strategies to determine the best method.
8. Monitor field populations of pest plants to:
    a) Determine if the biocontrol agent establishes self-perpetuating field populations
    b) Understand plant population dynamics to have a baseline to measure bioagent effects, especially if they are sub-lethal and subtle, and to know what portions of life history to watch
9. Study effectiveness of the agents for controlling the target plant. Monitor plant populations with and without the agent to determine any impacts.
10. Study the means of integrating biocontrol into overall management plans for the target plant.

In Florida, classical biological control of invasive non-native plants in non-agricultural areas has focused on aquatic weeds. The first such biocontrol agent introduced was the alligatorweed flea beetle (*Agasicles hygrophila*) in 1964 for control of alligatorweed (*Alternanthera philoxeroides*). Subsequently, the alligatorweed thrips (*Aminothrips andersoni*) was released in 1967 and the alligatorweed stem borer (*Vogtia malloi*) in 1971. The flea beetle and stem borer proved to be fairly effective for suppressing growth of alligatorweed, although harsh winters can reduce their populations. Less effective have been introductions of the water hyacinth weevils (*Neochotina eichhorniae* and *N. bruchi*), released in 1972 and 1974, and the water hyacinth borer, released in 1977 (*Sameodes albigutalis*) for water hyacinth control. Likewise, effectiveness of a weevil (*Neohydronomous affinis*) and a moth (*Namangama pectinicornis*) released for control of water lettuce has been unpredictable. Water hyacinth and water lettuce continue to be problems that require management by other methods, such as herbicide and mechanical harvesting. Current biological control research is focused on hydrilla, water hyacinth, melaleuca, Brazilian pepper, and Old World climbing fern.

Melaleuca snout beetles are damaging melaleuca stands and are also showing signs of range expansion after initial releases in 1997. The second melaleuca agent (a psyllid) was released in April 2002. The first Brazilian pepper insects and additional melaleuca-damaging insects may be approved for release in Florida within a few years. Overseas surveys and host specificity screening for insects found feeding upon Old World climbing fern in its native range are ongoing.

Introduction of animals, such as cattle, sheep, goats, or weed-eating fish, may also be used to control certain invasive plants. However, the environmental impacts of using such non-selective herbivores in natural areas should be carefully considered before implementation.

## Herbicides

Herbicides are pesticides designed to control plants. They are a vital component of most control programs and are used extensively for exotic plant species management in South Florida.

## Herbicide Application Methods

**Foliar applications.** A herbicide is diluted in water and applied to leaves with aerial or ground equipment. Foliar applications can either be directed to minimize damage to non-target vegetation or they can be broadcast. Broadcast applications are used where damage to non-target vegetation is not a concern, or where a selective herbicide is used.

**Basal bark applications.** A herbicide is applied, commonly with a backpack sprayer, directly to the bark around the circumference of each stem/tree at a height of up to 15 inches above the ground.

**Frill or girdle (sometimes called "hack-and-squirt") applications.** Cuts into the cambium are made completely around the circumference of the tree, with no more than three-inch intervals between cut edges. Continuous cuts (girdle) are sometimes used for difficult-to-control species and large trees. Herbicide (concentrated or diluted) is applied to each cut until the exposed area is thoroughly wet. Frill or girdle treatments are slow and labor intensive, but are sometimes necessary in mixed communities to kill target vegetation and minimize impacts to desirable vegetation.

**Stump treatments.** After cutting and removing large trees or brush, a herbicide (concentrated or diluted) is sprayed or painted onto the cut surface. The herbicide is usually concentrated on the cambium layer on large stumps, especially when using concentrated herbicide solutions. The cambium is next to the bark around the entire circumference of the stump. When using dilute solutions the entire stump is sometimes flooded (depending on label instructions) with herbicide solution.

**Soil applications.** Granular herbicide formulations are applied by hand-held spreaders, by specially designed blowers, or aerially.

## Where Herbicides Can Be Used

A pesticide, or some of its uses, is classified as "restricted" if it could potentially harm humans or the environment, unless it is applied by certified applicators who have the knowledge to use these pesticides safely and effectively. Although none of the herbicides commonly used for invasive plant control in the Everglades is classified as restricted-use, the basic knowledge of herbicide technology and application techniques that are needed for safe handling and effective use of any herbicides can be obtained through restricted-use pesticide certification training. All District applicators and contractor supervisors are required to obtain and maintain this certification before they apply herbicides in the Everglades Protection Area.

No pesticide may be sold in the United States until the U.S. Environmental Protection Agency (USEPA) has reviewed the manufacturer's application for registration and determined that the product's use will not present unreasonable risk to humans or the environment.

The USEPA approves the use of pesticides on specific sites, i.e., for use on individual crops, terrestrial non-crop areas, or aquatic settings. Only those herbicides registered by the USEPA specifically for use in aquatic sites can be applied to plants growing in lakes, rivers, canals, etc. For terrestrial uses, the USEPA requires herbicide labels to contain the statement: "Do not apply directly to water, to areas where surface water is present, or to intertidal areas below the mean high-water mark." The herbicide Rodeo® is registered for aquatic use and can be applied directly to water. Certain, but not all, herbicide products that contain 2,4-D can also be applied directly to water. The state supplemental special local need label for the imazapyr-containing product Arsenal® (EPA SLN NO. FL-940004) allows government agencies and their contractors to use it to control melaleuca and Brazilian pepper growing in water.

## Herbicide Toxicity to Wildlife

Invasive plant management is often conducted in natural areas with the purpose of maintaining or restoring wildlife habitat. Therefore, it is essential that the herbicides themselves are not toxic to wildlife. Herbicides used for invasive plant control in the Everglades have shown a very low toxicity to wildlife on which they have been tested, with the exception of the relatively low $LC_{50}$ (0.87 ppm) of triclopyr ester and fluazifop (0.57 ppm) for fish, neither of which can be applied directly to water. Ester formulations are toxic to fish because of irritation to their gill surfaces. However, because triclopyr ester and fluazifop are not applied directly to water, are adsorbed by soil particles, and have low persistence, exposure is low, which results in little risk when properly used.

## Manual and Mechanical Removal

Manual removal of exotics is very time consuming but is often a major component of effective invasive plant control. Seedlings and small saplings can sometimes be pulled from the ground, but even small seedlings of some plants have tenacious roots that will prevent extraction or cause them to break at the root collar. Plants that break off at the ground will often re-sprout, and even small root fragments left in the ground may sprout. Repeated hand pulling or follow-up with herbicide application is often necessary. Removal of uprooted plant material is also important. Stems and branches of certain species (i.e., melaleuca) that are laid on the ground can sprout roots, and attached seeds can germinate. If material cannot be destroyed by specific methods, such as burning, it is best to pile it in a secure area that can be monitored and kill any new plants that appear.

Mechanical removal involves the use of bulldozers or specialized logging equipment to remove woody plants. Intense follow-up with other control methods is essential after using heavy equipment because soil disturbance creates favorable conditions for re-growth from seeds and root fragments, as well as re-colonization by invasive, non-native plants. Mechanical removal using heavy equipment may not be appropriate in natural areas because of the risk of soil disturbance to non-target vegetation.

In aquatic environments, mechanical controls include self-propelled harvesting machines, draglines, cutting boats, and other machines, most of which remove vegetation from the waterbody. These systems generally are used for clearing boat trails, high-use areas, or locations where immediate control is required, such as flood control canals and around water control structures.

## Cultural Practices

Prescribed burning and water-level manipulation are cultural practices used in management of pastures, rangelands, and commercial forests, and in some situations may be appropriate for vegetation management in natural areas. Knowledge of land-use history is critical in understanding the effects of fire and flooding on the resulting plant species composition. Past practices affect soil structure, organic content, seed bank (both native and invasive exotic species), and species composition. While there is evidence that past farming and timber management practices will greatly influence the outcome of cultural management, very little is known about the effects of specific historical practices. Similar management practices conducted in areas with dissimilar histories may achieve very different results. Even less is known about the effects of invasives entering these communities and the subsequent management effects of fire on altered communities.

Understanding the reproductive biology of the target and non-target plant species is critical to effective use of any control methods, but particularly so with methods, such as fire management, that often require significant preparation time. Important opportunities exist when management tools can be applied to habitats where non-native invasive species flower or set seed at different times than the native species.

### *Prescribed Burning*

Fire is a normal part of most Florida ecosystems, and native species have evolved varying degrees of fire tolerance. Throughout much of the Everglades, suppression of fire has altered historical plant communities. Within these communities the fire-tolerant woody species have lingered in smaller numbers, and less fire-tolerant species have replaced ephemeral herbs. Little is known about the amount, frequency, timing, and intensity of fire that would best enhance the historically fire-tolerant plant species, and even less is known about how such a fire management regime could best be used to suppress invasive species. Single fires in areas with a history of many years of fire suppression are unlikely to restore historical species composition. Periodic fires in frequently burned areas do little to alter native species composition.

Invasion of tree stands by exotic vines and other climbing plants, such as Old World climbing fern, on Everglades tree islands has greatly increased the danger of canopy (crown) fires and the resulting death to mature trees. The added biomass by invasive plants can result in hotter fires and can greatly increase the risk of fires spreading to inhabited areas. In such situations, use of fire to reduce the standing biomass of invasive species may protect remaining plant populations better than if nothing were done, even though impacts to non-target native species would occur.

### *Water Level Manipulation*

Some success has been achieved by regulating water levels to reduce invasive plant species in aquatic and wetland habitats. De-watering aquatic sites reduces standing biomass, but little else is usually achieved unless the site is rendered less susceptible to repeated invasion when re-watered. Planting native species may reduce the susceptibility of aquatic and wetland sites in some cases.

In most situations, water level manipulation in reservoirs has not provided the degree of invasive plant control that was once thought achievable. Ponds and reservoirs can be constructed with steep sides to attempt to reduce invadable habitat, and levels can be avoided that promote invasive species, but these management options are rarely adaptable to natural areas.

Carefully timed water level increases following herbicide treatments, mechanical removal, or fire management of invasive species can sometimes control subsequent germination and, with some exotic species, re-sprouting.

## Priority Species

As required by the Everglades Forever Act, the District assembled a meeting in 1996 with representatives from the Florida Department of Environmental Protection (FDEP), the U.S. Army Corps of Engineers (USACE), the U.S. Fish and Wildlife Service (USFWS), and the National Park Service (Everglades National Park and the Big Cypress National Preserve). The purpose of this meeting was to compile a list of invasive exotic species that were considered the greatest threats to the Everglades. This list was not derived from the Florida EPPC list Category I invasive plant list; rather, it was a collaborative effort to list “priority species” for the Everglades Protection Area. Several factors were considered in evaluating these plant species, including:

- Does the species reproduce rapidly?
- Does the species shift native plant community composition by displacing and/or shading out native plant species and/or altering fire ecology?
- Is the species well adapted to the conditions (i.e., hydroperiod, fire regime) of the Everglades Protection Area?
- Is the species widespread in the Everglades Protection Area? If not, does the species have the potential to rapidly expand?
- Does the species have the potential to spread into remote areas of the Everglades Protection Area?

## PRIMARY EXOTIC SPECIES OF CONCERN IN THE EVERGLADES PROTECTION AREA

### Melaleuca quinquenervia

**Common Names:** Melaleuca, paper-bark, cajeput, punk tree, white bottlebrush tree

**Synonymy:** *Melaleuca leucadendron* (L.) L. misapplied

**Origin:** Australia, New Guinea, and the Solomon Islands

**Family:** Myrtaceae, myrtle family

**Botanical Description**: Evergreen tree to 33 m tall, with a slender crown and soft, whitish, many-layered, peeling bark. Leaves alternate, simple, grayish green, narrowly lance shaped, to 10 cm long and 2 cm wide, with a smell of camphor when crushed. Flowers in creamy white “bottle brush” spikes to 16 cm long. Fruit a round, woody capsule, about 3 mm wide, in clusters surrounding young stems, each capsule holding 200 to 300 tiny seeds.

**Ecological Significance**: In its native range, melaleuca grows in low-lying flooded areas and is especially well adapted to ecosystems that are periodically swept by fire. These are common conditions in South Florida, making the region an ideal habitat for colonization.

Melaleuca was introduced to Florida in 1906 (Fairchild, 1947) and scattered aerially over the Everglades in the 1930s to dry up “useless swampland” (Austin, 1978). It is hardy and fast growing. These characteristics spurred its use as an ornamental landscape tree, as agricultural windrows and protective living “guard rails,” and as soil stabilizers along canals. Melaleuca was recommended as late as 1970 as “one of Florida’s best landscape trees” (Watkins, 1970).

Melaleuca readily invades canal banks, pine flatwoods, cypress swamps, and uninterrupted sawgrass prairies of South Florida (Myers, 1975; Austin, 1978; Woodall, 1981b, 1982; Duever et al., 1986; Nelson, 1994). It grows extremely fast, producing dense stands that displace native plants, diminish animal habitat, and provide little food for wildlife (Laroche and Ferriter, 1992).

**Life History:** Melaleuca prefers seasonally wet sites, but also flourishes in standing water and well-drained uplands (Laroche, 1994b). Saplings are often killed by fire, but mature trees can survive fire and severe frost damage (Woodall, 1981). Melaleuca grows one to two m per year, easily re-sprouts from stumps and roots, and is capable of flowering within two years from seed (Laroche, 1994b). Melaleuca flowers and fruits all year, producing up to 20 million wind-borne seeds per year per tree and is able to hold viable seed for a massive, all-at-once release when stressed (Woodall, 1983). Melaleuca releases volatile oils into the air, especially when blooming, causing respiratory irritation, asthma attacks, headaches, and/or rashes in some people (Morton, 1971b).

**Distribution:** Melaleuca has been found naturalized in Florida as far north as Hernando, Lake, and Brevard counties (Mason, 1997; Wunderlin et al., 2000). It is reported from natural areas in 16 Central and South Florida counties (EPPC, 1996). Melaleuca grows equally well in the deep peat soil of Water Conversation Area 1 (WCA-1) and in the inorganic, calcareous soil of Everglades National Park. In general, wetland areas, such as sawgrass prairie, are more susceptible than drier, upland areas.

Before state and federal control operations were initiated in 1990, melaleuca was distributed throughout South Florida. Pioneering, or "outlier," melaleuca had invaded the Holy Land, the interior of Everglades National Park, and WCA-2A. Light-to-moderate infestations occurred in WCA-3 and at the western edge of the East Everglades Acquisition Area. Moderate-to-heavy infestations occurred in the Loxahatchee National Wildlife Refuge, Big Cypress National Preserve, WCA-2B, Lake Okeechobee, and in wetlands in Miami-Dade, Broward, Lee, and Collier counties. Baseline surveys in the early 1990s showed that melaleuca had invaded approximately 197,640 hectares in South Florida (Ferriter, 1999b).

**Control:** There are differing perspectives on the role of melaleuca in South Florida. Melaleuca's potential spread in South Florida is considered by some experts to be unlimited and could ultimately encroach on all open land (Hofstetter, 1991a); or, melaleuca could be limited to under-utilized niches in the relatively young Florida landscape (Myers, 1975). Acknowledgement of such alternative views embraces their common thread: melaleuca needs to be controlled despite whether it could ultimately cover the peninsula.

The integrated management of melaleuca requires a combination of control techniques to be effective. Essential elements of effective management include herbicidal, mechanical, physical, and biological control. Comprehensive descriptions for each of these management techniques are located in the "Invasive Plant Management Tools" section of this chapter.

The melaleuca management program is based on the quarantine strategy as described by Woodall, 1981. The least-infested areas (outliers) are addressed first in order to stop the progression of the existing population. The first phase of control targets all existing trees and seedlings in a given area. Using navigational equipment, work crews return to the same site in succeeding years to remove resulting seedlings from control activities of previous years. A successful control operation consists of three phases:

- Phase I: Focus on the elimination of all mature trees and seedlings present in an area.
- Phase II: Previously treated sites are revisited for follow-up treatment to control trees previously missed and remove seedlings which may have resulted from control activities of the preceding year.

- Phase III: Long-term surveillance and inspection of previously treated sites to monitor the effectiveness of the control program and maintain re-infestation levels as low as possible.

Single-tree herbicide applications are most commonly delivered as a frill-girdle or cut-stump treatment. The Arthur R. Marshall Loxahatchee National Wildlife Refuge and Everglades National Park (ENP) programs favor the cut-stump technique because trees are felled, limiting the subsequent seed dissemination. The District uses a combination of two individual ground treatment techniques, often leaving a ring of trees standing at each work location and felling the remaining trees. Standing trees alert the recreating public to hidden stumps, mitigating navigation hazards. The disadvantage, however, is that seed pods dry and seeds can be wind-blown several hundred feet from the treatment site.

The District and the ENP also use aerial applications of herbicides to control large monocultures. This provides cost-effective control in areas where non-target damage is minimized. Control of outlier trees is coordinated with the aerial treatment, and the trees are typically treated, as described above, by ground crews.

Direct herbicide application can still result in non-target effects where tree densities are high. Aerial application of herbicides may, in some cases, cause less non-target damage to native and herbaceous groundcover. It may also result in less herbicide being used on a site and, in some situations, may lower the cost of initial treatment. Manual removal of seedlings may not be advisable in all situations due to the percentage of roots broken below the ground surface. In addition, the soil disturbance that results may stimulate more seeds to germinate. Mechanical removal using heavy equipment is best suited for rights-of-way and other similar areas where routine maintenance follows and site disturbance is not a concern.

A key component of an effective and long-lasting melaleuca management program is the introduction of biological control agents. Without biological control, melaleuca elimination will be much more expensive and could not be truly integrated. The current investigation into biological organisms will most likely result in the introduction of seed and sapling feeders. The first introductions of a melaleuca snout beetle *(Oxyops vitiosa*) began in April 1997. As of July 2001, more than 17,000 larvae and 192,000 adults have been released at 140 different locations in nine counties. Preliminary results show that the insect is causing damage to new growth on melaleuca at several release sites. The melaleuca snout beetle is the first of a suite of insects that are being studied for release.

A new biocontrol for melaleuca was released from quarantine in February 2002. Approximately 150,000 psyllid (*Boreioglycaspis melaleucae*) have now been released and the agent has established itself at eight sites in South Florida. Populations are building quickly and have spread as much as 267 meters from release points. Nymphs suck the plant juices and inject a phytotoxic saliva that kills the tissue surrounding the feeding site. Small potted plants die within two months of a severe infestation. Significant impact is expected at field sites next winter, when the plants produce a flush of new foliage. Entomologists analyzing the problem estimate that at least five insect species will be required to effectively suppress the melaleuca's reproductive capacity.

Once introduced, several years are generally required for introduced populations to build to effective levels. In the interim and throughout the biocontrol introduction phase, herbicidal and mechanical controls will be required to reduce current infestations and prevent their spread into currently uninfested areas.

Through regional control efforts steady progress has been made, and today large, untreated monocultures of melaleuca are limited to WCA-2B, the Loxahatchee National Wildlife Refuge, the East Everglades Acquisition area, the Everglades buffer strip, and wetlands in Miami-Dade, Broward and Lee counties. Control efforts by local, state, and federal land management agencies have resulted in a decrease in melaleuca acres.

**New initiatives:** The Area-wide Management Evaluation of Melaleuca (TAME Melaleuca) was recently established under the USDA Agricultural Research Service's (ARS's) Area-wide Pest Management initiative. The goal of this five-year project is to demonstrate the effectiveness of an integrated approach for control of melaleuca that can be applied in invaded habitats in the United States and beyond. As described above, current control efforts concentrate on an individual tactic, with little integration of alternative approaches. This project represents an area-wide demonstration of multiple control tactics and their combined effectiveness. Land managers will have an opportunity to see different strategies in real-life settings and adapt techniques to address their site-specific melaleuca problems. Funding associated with this grant will allow work to be initiated on private lands, defraying the cost of melaleuca control for private landowners.

The USDA ARS plans to distribute limited funds to selected locations to develop TAME Melaleuca demonstration sites. Project leaders will work with land managers from each demonstration site to develop site-specific integrated melaleuca management plans. An annual budget of $35,000 per site for five years is available to defray management cost increases that may arise due to participation in TAME Melaleuca. This is a unique opportunity for interested land managers – both public and private – to receive financial and technical support for using integrated melaleuca management tactics they would otherwise consider too complicated, costly, or risky.

## Lygodium microphyllum

**Common Name:** Old World climbing fern

**Synonymy:** *Lygodium scandens* (L.) Sw., *Ugena microphylla* Cav.

**Origin:** Tropical Asia, Africa, and Australia

**Family:** Lygodiaceae, climbing fern family

**Botanical description:** Fern with dark brown, wiry rhizomes and climbing, twining fronds of indeterminate growth to 30 m long; main rachis (leaf stalk above petiole) wiry, stem-like. Leafy branches off main rachis (constituting the pinnae) once compound, oblongish in overall outline, 5 to 12 cm long. Leaflets (pinnules) usually un-lobed, stalked, articulate (leaving wiry stalks when detached). Leafblade tissue usually glabrous below. Fertile leaflets of similar size, fringed with tiny lobes of enrolled leaf tissue covering the sporangia along the leaf margin.

**Ecological significance:** There are two species of exotic climbing fern naturalized in Florida. Old World climbing fern is native to wet tropical and subtropical regions of Asia, Africa, and Australia. It has become a serious threat to South Florida natural areas, especially the Everglades, where it is increasing in density and range. Japanese climbing fern (*Lygodium japonicum*) is native to temperate and tropical Asia and occurs from eastern Texas through the southern states to North Carolina and North Florida. Japanese climbing fern has not yet been found within the EPA. Old World climbing fern has reached critical mass in South Florida such that new populations, presumably from wind-borne spores, are constantly being reported by natural resource managers and private landowners throughout the southern peninsula.

Old World climbing fern invades many freshwater and moist habitats in Florida. It is common in cypress swamps, pine flatwoods, wet prairies, sawgrass marshes, mangrove communities, and Everglades tree islands (Jewell, 1996; Pemberton and Ferriter, 1998). This plant seriously alters fire ecology, which is important to maintaining Florida habitats. Prescribed burns and wildfires that normally stop at the margins of flooded cypress sloughs will burn through areas infested with this fern. Burning mats of the lightweight fern break free during fires, and are kited away by heat plumes, leading to distant fire spotting. Additionally, the plant acts as a flame ladder, carrying fire high into native tree canopies. Under natural conditions fire rarely enters the tree canopy. Canopy fires are deadly to native cypress forests and pine flatwoods. Old World climbing fern has caused the loss of some canopy trees with such crown fires, as well as a loss of native epiphytes and bromeliads residing on tree trunks (Roberts, 1996).

Old World climbing fern forms dense mats of rachis plant material. These thick, spongy mats are slow to decompose, exclude native understory plants and can act as a site for additional fern colonization. It is difficult for other plant species to grow through the dense mat made by this fern, reducing plant diversity. Large expanses of fern material also may alter drainage and water movement.

**Life history:** Wiry Old World climbing fern rhizomes are able to accumulate into dense mats one meter or more thick above native soil. Vegetative growth and production of fertile pinnules continues throughout the year. Spores can germinate in 6-7 days, and 5-month-old spores retain an 80 percent germination rate (Brown, 1984). Fertile pinnules are usually produced where plants receive sunlight. Such exposed locations also aid wind-borne dispersal of the spores. Old world climbing fern often establishes first at pineland/wetland ecotones. It is usually killed back by fire but not eliminated, and re-growth is common (Maithani et al., 1986).

**Distribution:** The center of dispersal in Florida is reported by Beckner, 1968, and Nauman and Austin, 1978 as the Loxahatchee River Basin in southern Martin and northern Palm Beach counties. By 1993 the fern had expanded into western Martin County and central Palm Beach County. It is now spreading rapidly throughout the southern part of the state. Results from the 1993 District regional survey showed that Old World climbing fern occupied an estimated 10,935 hectares in South Florida. By 1997 this number had climbed to 15,800 hectares (Pemberton and Ferriter, 1998), and by 1999 the species was present in more than 43,000 hectares.

The tree islands of the northern Everglades (WCA-1) are significantly impacted by Old World climbing fern. Large tree islands are completely blanketed with this plant. Recent reports indicate the fern is spreading south through WCA-2 and WCA-3, the Big Cypress National Preserve, and Lee, Collier, and Miami-Dade counties. A large infestation totaling approximately 1,000 acres was discovered in the Ten Thousand Islands area of Everglades National Park (ENP) in 2000 (Tony Pernas, personal communication).

Increased hydroperiod does not seem to have an effect on this species, as it has expanded greatly in areas that have experienced several years of higher-than-normal water levels. This species is not restricted to elevated Everglades tree islands, as it has been noted growing in open, flooded sawgrass marshes in the Loxahatchee National Wildlife Refuge (Jewell, 1996). Old World climbing fern threatens to dominate many native plant communities in south and central Florida within the next decade (Ferriter, 1999a).

**Control:** Control options are only now being explored. A biological control program funded by the District has been implemented, but it could be years before any control agents are introduced (Pemberton, 1998). Fire and flooding do not appear to be stand-alone options based on preliminary studies. When fire kills most above-ground portions of this vine, it does not kill the plant. It also appears that flooding will not kill this plant, though flooded soils may limit its establishment.

Herbicides and herbicide application techniques are currently being evaluated and refined (Stocker et al., 1997). The District has initiated several studies to monitor the impacts of aerial herbicide treatments to non-target native plant communities. Preliminary results from winter treatments of Old World climbing fern in deciduous plant communities (i.e. *Taxodium*) show promise. In 2000, ENP and the District partnered to conduct a large-scale aerial treatment of Old World climbing fern in the remote western Everglades. The District plans to conduct experimental applications of herbicides on evergreen Everglades tree islands in the Refuge in 2001. Results of these treatments will be monitored to assess treatment efficacy and non-target damage. The District, the ENP and the Refuge are closely coordinating monitoring and control efforts and hope to develop an integrated strategy to contain and control this species in the EPA.

## Schinus terebinthifolius

**Common Names**: Brazilian pepper, Florida holly, Christmas berry, pepper tree

**Synonymy:** None

**Origin:** Brazil, Argentina, Paraguay

**Family:** Anacardiaceae, cashew family

**Botanical Description:** Evergreen shrub or tree to 13 m tall, often with multi-stemmed trunks and branches arching and crossing, forming tangled masses. Leaves alternate, odd-pinnately compound with three to 11 (usually seven to nine) elliptic-oblong leaflets, 2.5 to 5 cm long, with upper surfaces dark green (lateral veins obvious, lighter in color), lower surfaces paler, and leaflet margins often somewhat toothed. Leaves aromatic when crushed, smelling peppery or like turpentine. Flowers unisexual (dioecious), small, in short-branched clusters at leaf axils of current-season stems; petals: five, white, to 2 mm long. Fruit a small, bright-red, spherical drupe.

**Ecological Significance:** Brazilian pepper was imported as an ornamental in the 1840s (Barkley, 1944). It has bright red fruit and shiny, green leaves that increased its popularity as a substitute for holly in Florida, quickly earning the misnomer Florida holly (Morton, 1971a). Its fruit is commonly consumed by frugivorous birds. The dispersal of seeds by these birds, namely mockingbirds, cedar waxwings, and especially migrating robins, has been responsible for the spread of Brazilian pepper into outlying, non-Brazilian pepper-dominated ecosystems, especially those that include perches, such as trees and utility lines (Ewel et al., 1982). Raccoons and opossums are known to ingest the fruit, and their stools provide additional nutrients for seed germination and seedling growth. Brazilian pepper has invaded a variety of areas, including, but not limited to, fallow farmland, pinelands, hardwood hammocks, roadsides, and mangrove forests in areas with a high degree of disturbance and in natural areas with little disturbance (Woodall, 1982; Ferriter, 1997). Brazilian pepper forms dense thickets of tangled woody stems that completely shade out and displace native vegetation. It has displaced some populations of rare listed species, such as the beach Jacquemontia (*Jacquemontia reclinata* House, U.S. and Fla. Endangered), and beach star (*Remirea maritima* Aubl., Fla. endangered).

**Life history:** Brazilian pepper sprouts easily from the trunk and roots, even if the plant is damaged. It flowers every month of the year in Florida, with the most intense period of flowering in the fall. Brazilian pepper fruits profusely in southern and central Florida, with wildlife consumption of fruits contributing to the spread of seeds (Ewel et al., 1982). It produces chemicals in its leaves, flowers, and fruits that irritate human skin and respiratory passages (Morton, 1978; Ewel et al., 1982).

**Distribution:** Brazilian pepper is naturalized in most tropical and subtropical regions, including other South American countries, parts of Central America, Bermuda, the Bahama Islands, the West Indies, Guam, Mediterranean Europe, North Africa, southern Asia, and South Africa. In the United States it occurs in Hawaii, California, southern Arizona, and Florida (as far north as Levy and St. Johns counties and as far west as Santa Rosa County) (EPPC, 1996).

Brazilian pepper does not become established in deeper wetland communities and rarely grows on sites inundated longer than three to six months. In the ENP, for example, it is absent from marshes and prairies with hydroperiods exceeding six months, as well as from tree islands with closed canopies (LaRosa et al., 1992). Once established, however, Brazilian pepper can tolerate extended periods of shallow water inundation. The effects of deep-water flooding on established Brazilian pepper populations are still unclear.

Concern over the occurrence of Brazilian pepper in salt-tolerant plant communities, e.g., mangrove forests in southern Florida, especially in the ENP, led Mytinger and Williamson (1987) to investigate Brazilian pepper's tolerance to saline conditions. Seed germination and transplanted seedlings did not succeed at salinities of 5 parts per trillion (ppt) or greater, which would largely exclude it from becoming established in mangrove forests. However, invasion of saline communities can occur if salinity declines due to changes in drainage patterns resulting from natural phenomena or human activities.

Within the EPA, Brazilian pepper has invaded most of the canal levees and much of the powerline rights-of-way. Some of the WCA-1 tree islands have been colonized to varying degrees by this species. By far the greatest areal coverage of Brazilian pepper within the EPA is an area called the Hole-in-the-Doughnut (HID). Situated within the boundaries of Everglades National Park, the HID comprises approximately 4,000 hectares of previously farmed lands (farming ceased in 1975). More than 40 percent (1,600-plus hectares) of this area has been invaded by a dense forest of Brazilian pepper. This species also has infested more than 40,000 hectares in the isolated Ten Thousand Islands and is widely scattered throughout the ENP, occurring in all habitats, but particularly in disturbed areas. Brazilian pepper is now estimated to occupy over 400,000 ha in central and South Florida (Ferriter, 1997; Wunderlin et al., 2000).

**Control:** ENP scientists have researched a number of restoration techniques over the years. Only the complete removal of the disturbed substrate has resulted in recolonization by native vegetation to the exclusion of Brazilian pepper. The ENP initiated a full-scale substrate removal project for the entire HID in 1996. To date, eight percent of what was once Brazilian pepper forest has been restored to native vegetation. The project is funded through the year 2016.

Along canal levees, highways, and powerline rights-of-way, most control work involves the selected use of herbicides or the use of heavy equipment to physically remove Brazilian pepper, followed by a herbicide application. Large, single trees are usually treated with a basal bark herbicide application. This treatment provides for the greatest selectivity, with no non-target effects. In dense stands foliar herbicides may be used and are most effective when applied aerially.

Biological controls have not yet been approved for general release against Brazilian pepper, though District-sponsored research is ongoing. The University of Florida Department of Entomology and Nematology has been investigating insect vectors of Brazilian pepper since 1994. Exploratory surveys conducted in Brazil have identified several insects as potential biological control agents. Three insect species – a thrips (*Pseudophilothrips ichini*), a sawfly (*Heteroperreyia hubrichi*), and a leaf roller (*Episimus utilis*) – have been selected for further study (Cuda et al., 1999). Host specificity testing for the sawfly has been completed, and a petition to release this species has been submitted.

## Casuarina equisetifolia, Casuarina glauca

**Common Names:** Australian pine, beefwood, ironwood, she-oak, horsetail tree

**Synonymy:** *Casuarina littorea* L. ex Fosberg & Sachet, *C. litorea* Rumpheus ex Stickman

**Origin:** Australia, South Pacific Islands, Southeast Asia

**Family:** Casuarinaceae, beefwood family

**Botanical description:** Evergreen tree to 46 m tall, usually with single trunk and open, irregular crown. Bark reddish-brown to gray, rough, brittle, peeling. Branchlets pine-needle-like, grayish-green, jointed, thin (< 1mm wide), 10 to 20 cm long, minutely ridged, hairy in furrows. Leaves reduced to tiny scales, six to eight in whorls encircling joints of branchlets. Flowers unisexual (monoecious), inconspicuous, female in small axillary clusters, male in small terminal spikes. Fruit a tiny, one-seeded, winged nutlet (samara) formed in woody, cone-like clusters (fruiting heads), these brown, to 2 cm long and 1.3 cm wide.

**Ecological significance:** Australian pine was introduced to Florida in the late 1800s (Morton, 1980). It naturalized since the early 1900s along coastal dunes (Small, 1927). Australian pine was planted extensively in the southern half of the state as windbreaks and shade trees (Morton, 1980). It is salt tolerant and seeds freely throughout the area, growing even in front-line dunes (Watkins, 1970; Long and Lakela, 1971). Its rapid growth, dense shade, dense litter accumulation, and other competitive advantages are extremely destructive to native vegetation (Nelson, 1994). Australian pine can encourage beach erosion by displacing deep-rooted native vegetation. It can also interfere with the nesting of endangered sea turtles and the American crocodile (Klukas, 1969).

Three species of Australian pine trees invade Florida's wild lands. Since their introduction in the late 1800s, they have been widely planted throughout the southern peninsula. It was not until 1992 that the state banned the further propagation and sale of these trees as ornamentals. Australian pine grows very fast (1-3 meters per year), is salt-tolerant, and readily colonizes rocky coasts, dunes, sandbars, islands, and invades far inland moist habitats, such as the East Everglades Area of Everglades National Park (Morton, 1980). It forms dense forests, crowding out all other plant species. It has crowded out vast areas of natural vegetation along Florida's coastline where the public vehemently opposes any removal efforts.

**Life history:** Australian pine is not freeze tolerant and is sensitive to fire (Morton, 1980). It loses branches easily and topples in high winds (Morton, 1980). Australian pine produces allelopathic compounds that inhibit growth of other vegetation (Morton, 1980) and can easily colonize nutrient-poor soils by nitrogen-fixing microbial associations (Wilson, 1997). It reproduces prolifically by seed – as many as 600,000 to the kilogram – with seeds dispersed by birds (especially exotic parrots and parakeets), water, and wind (Morton, 1980). The fruiting heads of this species float (Maxwell 1984).

**Distribution:** Australian pine occurs throughout South Florida from Orlando south, on sandy shores and in pinelands. It occurs as far north as Dixie County on the West Coast and Volusia County on the East Coast (Wunderlin et al. 1995). Australian pine frequently colonizes disturbed sites, such as filled wetlands, road shoulders, cleared land, and undeveloped lots (Maxwell 1984).

Australian pine is mainly a problem along levee berms in the water conservation areas (WCAs). A large portion of the east Everglades and the southern saline glades (C-111 basin), as well as coastal areas of the Park, are heavily impacted. The seeds are wind-blown, carried by birds, and probably moved throughout the EPA via water flow in canals. Australian pine has a microbial association with nitrogen-fixing organisms that allows it to colonize and grow prolifically in nutrient-impoverished soils. This nitrogen-fixing capacity, combined with a lack of natural enemies, gives Australian pine a tremendous competitive edge over natural vegetation. Until recently, Australian pine was the dominant tree species growing along the EPA's canal levees. The largest remaining populations of Australian pine in the EPA are original plantings growing along S.R. 27 in Broward County and wild populations growing in the east Everglades area.

**Control:** Fire is sometimes effective in dense stands of Australian pine that have sufficient fuel on the ground. Larger trees usually re-sprout from the base and require some form of follow-up herbicide treatment. There is no biological control research being conducted on Australian pine at this time, though it is a good candidate for this control method. It is not likely that biological control will be an option in the near future due to the tree's popularity in urban landscapes and coastal communities.

The primary method of control is selective use of herbicides. Although several soil-active herbicides are effective, the most common control techniques involve basal bark and cut-stump herbicide applications. The District has nearly completed its control of mature Australian pine trees growing along canal levees of the EPA and in District-managed lands in the southern Everglades. Periodic follow-up is required to treat seedlings that arise from the residual seedbank. Re-treatment to deplete the existing seed bank is conducted prior to saplings maturing and flowering.

## Colubrina asiatica

**Common Names:** Latherleaf, Asiatic or common colubrina, hoop withe, Asian snakeroot

**Synonymy:** None

**Origin:** Old World

**Family:** Rhamnaceae, buckthorn family

**Botanical description:** Glabrous, evergreen, scrambling shrub with diffuse, slender branches to 5 m long; in older plants, stems to 15 m long. Leaves alternate, with slender petioles to 2 cm long; blades oval, shiny dark green above, 4 to 9 cm long and 2.5 to 5 cm wide, with toothed margins and producing a thin lather when crushed and rubbed in water. Flowers small, greenish-white, in short branched, few-flowered clusters at leaf axils; each with a nectar disc, five sepals, five hooded petals, and five stamens. Fruit a globose capsule, green and fleshy at first and turning brown upon drying, about 8 mm wide, with three grayish seeds.

**Ecological Significance:** Latherleaf is thought to have been brought to Jamaica in the 1850s by East Asian immigrants for traditional use as medicine, food, fish poison, and soap substitute (Burkill, 1935; Perry, 1980). It is noted as naturalized in the Keys and Everglades by Small, 1933 and as aggressively spreading along these coasts (Morton, 1976; Austin, 1978). Latherleaf invades marly coastal ridges just above the mean high-tide line (Russell et al., 1982), in tropical hammocks, buttonwood and mangrove forests, and tidal marshes (Schultz, 1992). It also forms thickets on disturbed coastal roadsides. Latherleaf can invade disturbed and undisturbed forest sites (Olmsted et al., 1981; Jones, 1996), forming thick mats of entangled stems up to several feet deep, and growing over and shading out native vegetation, including trees (Langeland, 1990; Jones, 1996). This species is of particular concern in Florida's coastal hammocks, where it threatens a number of rare, listed native plant species, such as mahogany, thatch palm, wild cinnamon, manchineel, cacti, bromeliads, and orchids (Jones, 1996). It is also now in every park in the Florida Keys, where it threatens rare natives, such as bay cedar and beach star.

**Life History:** Latherleaf requires considerable light, with seedling growth rate increasing where shade is removed; stems may grow 10 m in a single year (Schultz 1992). It forms adventitious roots where branches touch the ground, and vigorously re-sprouts from cut or injured stems. This species may reach seed-producing maturity within a year (Russell et al., 1982, Schultz 1992). In Florida it flowers most often in July, with fruits maturing in September (Jones, 1996), but is reported as flowering year-round (Long and Lakela, 1971; Wunderlin, 1982). Loose soil is usually required for germination, with seeds able to retain viability in soil for several years (Russell et al., 1982). Long-distance dispersal is aided primarily by storms and extreme tides, which allow ocean currents to carry away the buoyant, salt-tolerant fruits and seeds (Carlquist, 1966).

**Distribution**: Latherleaf is found naturally from eastern Africa to India, Southeast Asia, tropical Australia, and the Pacific Islands, including Hawaii, where it typically occurs as scattered plants on sandy and rocky seashores (Brizicky, 1964; Johnston, 1971; Tomlinson, 1980). From Jamaica it has spread in the New World to other Caribbean islands, Mexico, and Florida, with the aid of ocean currents and storm tides (Russell et al., 1982). It is now naturalized in Florida in coastal areas from Key West north to Hutchinson Island in St. Lucie County (Schultz, 1992).

Nowhere in Florida are the ecological effects of latherleaf more noticeable than in Everglades National Park (Jones, 1997). Latherleaf is well distributed throughout the Park's coastal areas. It occurs from the Ten Thousand Islands south to Cape Sable along the Gulf Coast and east along the northern fringe of Florida Bay to the Florida Keys. Latherleaf occupies approximately 500 hectares of the most remote areas of the Park. Coastal hardwood forests are among the most threatened plant communities in southern Florida. The aggressive colonization nature of latherleaf and its continued expansion into these areas is especially disconcerting.

Fortunately, there is no evidence of long-distance dispersal mechanisms on land that could further facilitate its spread inland. Storms and extreme tides appear to be the only dispersal agents.

Latherleaf was casually noted as existing in the Park until the 1970s, when large monotypic stands up to one hectare in area were observed along the coast of Florida Bay (Russell et al., 1982). In 1974, Park staff reported 130 ha of latherleaf growing at sites along the coast from Christian Point to Santini Bight, including some of the offshore keys. In 1980 a detailed vegetation and mapping study of the coast between Flamingo Bay and Joe Bay revealed 50 ha of high-density stands (Olmsted et al., 1981). Interpretation of 1987 color infrared aerial photographs (1:10,000 scale) of the Park by Rose and Doren, 1988, showed that the areal extent of medium-to-high-density latherleaf along the same stretch of coastline (Snake Bight to Joe Bay) was 230 ha. Photo interpretation of 1994-1995 USGS NAPP color infrared photographs (1:40,000 scale) by the University of Georgia's Center for Remote Sensing and Mapping Science has provided the latest information on the distribution of latherleaf in the Park. Low-to-high-density infestations of latherleaf covered nearly 420 ha for the same area. An 84-percent increase in latherleaf's extent over the seven-year period was reported. From this mapping data, it can be estimated that the areal extent of latherleaf may double every 10 years, spreading at the rate of approximately 25 ha per year.

**Control**: Latherleaf has been successfully managed in Biscayne National Park as well as on other public lands. Uprooting the young, shallow-rooted plants, cutting scandent stems, and applying herbicides, either cut-stump or basal bark, have proven effective (Langeland, 1990). Biological control is not currently available—a situation not likely to change anytime soon. To date, management efforts within the Park have been restricted due to funding limitations.

## Eichhornia crassipes

**Common names:** Water hyacinth, water orchid

**Synonymy:** *Piaropus crassipes* (Mart.) Britt.

**Origin:** Amazon basin

**Family:** Pontederiaceae, pickerelweed family

**Botanical description:** Floating aquatic herb, rooting in mud if stranded, usually in dense mats with new plantlets attached on floating green stolons. Submersed roots blue-black to dark purple, feathery, dense near root crown, tips with long dark root caps. Leaves formed in rosettes; petioles to 30 cm or more, spongy, usually inflated or bulbous, especially near base; leaf blades roundish or broadly elliptic, glossy green, to 15 cm wide. Inflorescence a showy spike above rosette, to 30 cm long. Flowers lavender-blue with a yellow blotch, to 5 cm wide, somewhat two-lipped; petals 6, stamens 6. Fruit a three-celled capsule with many seeds.

**Ecological Significance:** Water hyacinth is reported as a weed in 56 countries (Holm et al., 1979). It was introduced into the United States in 1884 at an exposition in New Orleans, reaching Florida in 1890 (Gopal and Sharma, 1981). By the late 1950s water hyacinth occupied about 51,000 ha of Florida's waterways (Schmitz et al., 1993). It grows at explosive rates, exceeding any other tested vascular plant (Wolverton and McDonald, 1979) and doubling its populations in as little as six to 18 days (Mitchell, 1976). In large mats, it degrades water quality and dramatically alters native plant and animal communities (Gowanloch, 1944; Penfound and Earle, 1948). Large mats of water hyacinth can collect around water control structures and impede flow.

**Life history:** Water hyacinth reproduces both vegetatively and sexually (Penfound and Earle, 1948; Gopal and Sharma, 1981). It quickly forms new rosettes on floating stolons; with stolons easily broken, the plants and mats are transported by wind and water. Leaves are killed back by moderate freezes, but quickly re-grow from the stem tip protected beneath the water's surface. Water hyacinth flowers year-round in mild climates, producing abundant seeds in developed mats (Penfound and Earle, 1948). Numerous seedlings are seen in conjunction with lake drawdowns.

**Distribution:** Water hyacinth now occurs globally in the tropics and subtropics and further north and south, where it can escape severe cold (Holm et al., 1977). It is found in 16 states, including throughout Florida, north to Virginia (and New York) and west to California and Hawaii (USDA, 1997).

Under ideal growing conditions these plants can increase their surface coverage by 25 percent each month when not managed (Langeland, 1988). The thick floating mats of vegetation block boating access within the EPA, clog water control structures, negatively impact water quality, and reduce native plant species. These plants are almost exclusively located in artificial environments. They are common in all canals and around most water control structures. In addition, they can often be found growing at the mouth of airboat trails that transect the canals. However, they do not appear to compete with native vegetation in the EPA away from these disturbed environments.

**Control:** Water hyacinth and water lettuce are both free-floating aquatic plants. They create similar problems and are similarly managed. Consequently, control methods for both species are discussed below.

The District conducts operations under permit from the FDEP and performs all work in accordance with both federal and state regulations. The District's primary goal is to implement a "maintenance control program." Florida state statute Chapter 372.925 defines maintenance control as "...a method of managing exotic aquatic plants in which control techniques are utilized in a coordinated manner on a continuous basis to maintain a plant population at the lowest feasible level." Maintenance control results in less use of herbicides, the deposition of less organic matter (from dead leaves and plants), less overall environmental impact by weeds, and reduced management costs.

Herbicides have been the primary method of controlling floating, exotic, aquatic weeds in the EPA. Herbicides used for management of these plants are diquat and 2,4-D. Both are fully approved by the U.S. Environmental Protection Agency (USEPA) for application to aquatic sites. Mechanical controls have been generally limited to work in and around structures where plants have modified discharge capacities and need to be physically removed. The process of mechanically harvesting water hyacinth and water lettuce is slow and expensive (10 to 15 times greater than with herbicides). Harvested plant biomass must be removed from the water to be effective, and near-shore disposal options are often limited, adding considerable cost to mechanical removal.

Mechanical harvesting cannot be considered a stand-alone option for floating weed management in the EPA canals. While insects have been introduced as biological controls for both species, they have not yet introduced the compliment of insect vectors to "control" plant growth. USDA-ARS biocontrol researchers have recently completed field assessments in Peru searching for and identifying candidate insects for study in U.S. quarantine. Herbicide applications remain the primary control method and are applied either by boat or by helicopter.

## Pistia stratiotes

**Common name:** Water lettuce

**Synonymy:** None

**Origin:** Africa or South America

**Family:** Araceae, arum family

**Botanical description:** Floating herb in rosettes of gray-green leaves, rosettes occurring singly or connected to others by short stolons. Roots numerous, feathery. Leaves often spongy near base, densely soft pubescent with obvious parallel veins, slightly broader than long, widest at apex, to 15 cm long. Flowers inconspicuous, clustered on small, fleshy stalk nearly hidden in leaf axils, with single female flower below and whorl of male flowers above. Fruit arising from female flower as a many-seeded, green berry.

**Ecological significance:** Water lettuce may have been introduced to North America either naturally or by humans (Stoddard, 1989). The plant was seen as early as 1774 by William Bartram in "vast quantities" several miles in length and, in some places, a quarter of a mile in breadth in the St. Johns River (Van Doren, 1928). It has been suggested that trade via St. Augustine, founded in 1565, may have provided an early avenue for introduction into the St. Johns watershed (Stuckey and Les, 1984). Water lettuce is capable of forming vast mats that disrupt submersed plant and animal communities. These mats can collect around water control structures and interfere with water movement and navigation (Attionu, 1976; Holm et al., 1977; Bruner, 1982; Sharma, 1984). It is considered a serious weed in Ceylon, Ghana, Indonesia, and Thailand and is at least present as a weed in 40 other countries (Holm et al., 1979).

**Life history:** Water lettuce reproduces rapidly by vegetative offshoots formed on short, brittle stolons. Rosette density varies seasonally, from fewer than 100 to more than 1,000 per square meter in South Florida (Dewald and Lounibos, 1990). Seed production, once thought not to occur in North America, is now considered important to reproduction and dispersal (Dray and Center, 1989). Water lettuce is not cold tolerant (Holm et al., 1977). It can survive for extended periods of time on moist muck, sandbars, and banks (Holm et al., 1977).

**Distribution:** Water lettuce is now one of the most widely distributed hydrophytes in the tropics (Holm et al., 1977). In North America it occurs in peninsular Florida and locally westward to Texas (Godfrey and Wooten, 1979). It is also found persisting in coastal South Carolina (Nelson, 1993). Water lettuce occurred in 68 public water bodies in Florida by 1982 and in 128 waterbodies by 1989 (Schardt and Schmitz, 1990) **>>>(check the year on this publication).<<<** In the Everglades region, water lettuce is mainly restricted to canals and around water control structures. It also occurs in the artificial waterbodies of the Park.

**Control:** See water hyacinth control section.

## SECONDARY SPECIES OF CONCERN IN THE EVERGLADES PROTECTION AREA

Other exotic species of concern in the Everglades are mainly restricted to the levee berms. These plants include: Java plum (*Syzygium cumini*), earleaf acacia, (*Acacia auriculforms*), ficus (*Ficus microcarpa*), bishopwood (*Bischofia javanica*), guava (*Psidium guajava*), Surinam cherry (*Eugenia uniflora*), lead tree (*Leucaena leucocephala*), climbing cassia (*Senna pendula*), wild taro (*Colocasia esculenta*), lantana (*Lantana camara*), Burma reed (*Neyraudia reynaudiana*), napiergrass (*Pennisetum purpureum*), kudzu (*Pueraria montana*), schefflera (*Schefflera actinophylla*) and torpedograss (*Panicum repens*). Hydrilla and hygrophila are submersed aquatic plants found mainly in canals and around water control structures.

Shoebutton ardisia is a shade-loving shrub originally reported from the Hole-in-the-Doughnut. It has spread into adjacent tropical hardwood hammocks in the Long Pine Key area of the Park (Seavey and Seavey, 1994) and was observed to have spread to the Flamingo Bay area in 1995 (Doren and Jones, 1997). Other species of concern in the Park are less widespread and are extremely variable in their distribution, the habitats they invade, and the size of their infestations. Several of these species have persisted from cultivation and have shown the ability to spread from their points of introduction. These species include sisal hemp (*Agave sisalana*), woman's tongue (*Albizia lebbeck*), orchid tree (*Bauhinia variegata*), mast wood (*Calophyllum antillanum*), Surinam cherry, lantana, lead tree, tuberous sword fern (*Nephrolepis cordifolia*), half flower (*Scaevola taccada*), ground orchid (*Oeceoclades maculata*), guava, oyster plant (*Rhoeo spathacea*), bowstring hemp (*Sansevieria hyacinthoides*), shefflera, arrowhead vine (*Syngonium podophyllum*), and tropical almond (*Terminalia catappa*). Infestations consist of scattered individuals, except in the case of sisal hemp, tuberous sword fern, ground orchid, oyster plant, bowstring hemp, and arrowhead vine, which are all species that spread vegetatively and produce locally dense populations. The coastal species mahoe (*Hibiscus tiliaceus*) and seaside mahoe (*Thespesia populnea*), as well as the grasses cogongrass (*Imperata cylindrica*), Burma reed and napiergrass, have reached the Park by natural expansion from outside sources and are represented by single plants and dense clones.

# INFORMATION GAPS AND FUTURE NEEDS

Rudimentary elements of a good invasive exotic plant management strategy – legislation, coordination, planning, research, education, training, and resource input – have been in place in Florida for many years. The plants identified above as primary exotic invasive species in the Everglades region are being controlled to some extent by most state or federal agencies. Unfortunately, there are dozens of other exotic species in the Everglades that have unknown distributions and invasive potentials. The threat of exotic invasive animals is also recognized but is not being addressed by any one agency. Funding and coordination for a comparable non-indigenous animal management program are badly needed. Little can be done without a committed effort to develop ecological understanding of the spread, effects, and behaviors of exotic animals in the Everglades.

Regardless of taxa, the invasiveness of a species is often somewhat slow to develop. Species that appear benign for many years, or even decades, can suddenly spread rapidly following events such as flood, fire, drought, long-term commercial availability, or some other factor. There is a need to recognize these species during their incipient phase or even prior to introduction to maximize available management resources.

## RESEARCH NEEDS

It is tempting to assume that once restoration efforts are achieved, results will include a reduced need to control exotic species in the Everglades. However, although it is true that the spread of some exotic species can be reduced by increasing hydroperiods (i.e., Brazilian pepper), there has been little or no research done to determine what effects long-range hydrologic changes or nutrient reductions will have on most of the other exotic species throughout the system. Ongoing tree island research has focused on the effects of high water, but has completely ignored the effects of exotic plants, such as Old World climbing fern. Nutrient enrichment studies have looked at changes to native flora but have excluded the study of exotics. Old World climbing fern, melaleuca, and Brazilian pepper have successfully invaded areas with the least apparent human alterations, including the mangrove zones of Southwest Florida and Big Cypress National Preserve. Exotic plant communities in the Everglades Stormwater Treatment Areas (STAs) will need to be monitored and measured as changes are made to the system's hydrology. A more comprehensive approach is necessary when looking at the long-term restoration process regarding the exotic plant species composition response. It is also necessary to educate the public and policymakers that invasive exotic species will always require some level of maintenance and that new introductions will have to cease to avoid future eradication costs.

Also, as previously mentioned, management of invasive animals remains a nascent field of study in the region, with little or no published material available to guide planners and resource managers.

## MANAGEMENT EFFORTS

Economic impacts of invasive species in the Everglades Protection Area cannot be directly drawn from the literature. Studies documenting the expansion of some species imply that control would be cheaper when populations are small (Laroche and Ferriter, 1992), but no direct analyses of the environmental and cultural costs and benefits of invasive plant control in the Everglades are available in the literature. The lack of such background information limits the strength of arguments supporting control of these pest species. Further, it might be argued that there should be no need to study such obvious catastrophes, yet basic foundational research is often needed to construct convincing arguments. A few citations quantify the costs, impacts, and benefits resulting from control of aquatic weeds in a few Florida waterbodies (Milon, et al., 1986; Colle et al., 1987), but none for wetlands, such as the Everglades Protection Area.

For many of the upland exotic plants, research has not focused on the most effective and current control methods. Specific controls for melaleuca, Brazilian pepper, and a few others have been the subject of both formal and informal research. For the majority of other species, only general guidelines of herbicide use or mechanical controls apply. A wide range of unknowns remains for each species. Additional research might show, for example, how to best control each plant in different settings, how to minimize non-target damage, or whether treatments during different seasons or stages of growth of each plant will affect results.

### Ecological Impacts of Invasive Species

Relatively little work has been done to investigate the ecological impacts of invasive species in the Everglades Protection Area. While it is easy to visually observe the density of an invasive exotic plant in a natural area, the question of the effect of that density on wildlife has not been extensively studied. Without specific published proof, resource managers can be somewhat "out on a limb" when arguing for support to manage invasive plants in the context of protecting ecological integrity of natural areas. Little research has been done to look at the effect of invasive exotic plants on nesting, denning, roosting, feeding, and foraging of Florida's indigenous wildlife.

Melaleuca (Ostrenko and Mazzotti, 1981; Sowder and Woodall, 1985; O'Hare et al., 1997) and Brazilian pepper (Gogue, 1974; Curnutt, 1989) have been found to decrease wildlife species diversity; however such studies are rare in the published literature. More publications have come from management, monitoring, or botanical investigations (Ferriter, 1997; Laroche, 1999). For most of the other invasive plants found in the Everglades Protection Area, very few publications are available of even a general nature, and of these, virtually none formally assess ecological impacts of each species.

## COORDINATION EFFORTS

There is a clear need for a comprehensive plan that incorporates broad and consistent strategies, reduces agency inconsistencies, and takes into account differing agency mandates to achieve the goal of controlling invasive species. This would result in a strategy that is appropriate for, applicable to, and coordinated with state and federal efforts to manage invasive species, both plants and animals, and which supports each agency in carrying out its role in the broader program of invasive species control. It is hoped that when complete, the NEWTT Assessment and Strategy will fill this need in the area of invasive plants. A similar effort is needed for non-indigenous animals in the Everglades Protection Area.

## MANAGEMENT AUTHORITIES AND REGULATIONS

Although U.S. regulations on the import of exotic species in general are extensive, there is virtually no regulation against bringing many exotic plant species into the United States. Barring the primarily agricultural weeds on the Federal Noxious Weed list, importation laws focus on plant pests, rather than pest plants. Insects and pathogens are extensively screened at ports of entry, but plants are allowed to enter this country virtually unimpeded. Up-front screening methods need to be developed to control new importation of exotic plant species. Australia and New Zealand have strict regulations regarding exotic plant importation. These countries have developed comprehensive “white lists” of plants permitted for import. Any plant not on the white list cannot enter either country without a risk assessment. At a minimum, state and federal agencies importing plants for food, fiber, or forage evaluation should have a protocol that screens plants for invasiveness prior to recommending new plant species for cultivation.

On the state level, the Federal Department of Agriculture and Consumer Services (FDACS) Division of Plant Industry staff do much to assist in the control of invasive exotic plants in natural areas. However, in a regulatory context plants on the FDACS noxious weed list are primarily listed because of their threat to agriculture rather than their threat to native ecosystems. While the FDACS Division of Forestry fights a whole host of invasive exotic plants in its state forests, most of the plants it controls are not even on the FDACS list.

In 1999, FDACS amended its list to include 11 new species that are a threat to natural areas: carrotwood (*Cupaniopsis anacardioides*); dioscorea (*Dioscorea alata* and *Dioscorea bulbifera*); Japanese climbing fern; Old World climbing fern; Burma reed; sewer vine (*Paederia cruddasiana*); skunkvine (*Paederia foetida*); kudzu; downy myrtle (*Rhodomyrtus tomentosa*); and wetland nightshade (*Solanum tampicense)*. The addition of these plants is a good indicator of a growing shift in agricultural rules and regulations to incorporate the protection of natural areas in their regulatory focus.

## BETTER SUPPORT FOR BIOLOGICAL CONTROL

Isolating, testing, and releasing a host-specific insect to control an invasive exotic plant in the United States can take more than a decade, as in the case of the melaleuca snout beetle. Once an insect has been properly selected and screened, it must be approved by a federal technical advisory group (TAG) and, in Florida, a state arthropod committee. Although the process is necessary, it can be extremely slow. There are no deadlines for review set by the committee(s), and the review process for each request for release does not seem to be a priority for staff at participating agencies, especially in the case of agents that target natural area weeds. The process needs to be streamlined and formalized. The final federal authorization for biological release comes from United States Department of Agriculture, Animal and Plant Health Inspection Service. This approval process is often very slow, as well.

Compounding the problem is a lack of specific biological control quarantine facility space in Florida for environmental weeds. The only quarantine facility currently available for this work in Florida is a small, outdated lab in Gainesville. Available space is shared with researchers screening biological controls for agricultural pests. This space limitation has restricted the number of agents the researchers can study, creating a serious bottleneck. After years of struggle, construction of a new quarantine facility is underway at the USDA site in Davie, Florida. This step forward is a positive one in light of the overwhelming need for additional biological control research.

## DEVELOP PUBLIC/PRIVATE PARTNERSHIPS

Invasive exotic species recognize no political boundaries. Natural resource managers increasingly recognize that parochial management approaches to these problems are ineffective. Without a regional approach, effective containment of a pest plant is impossible. This strategy has proven successful with the management of melaleuca on public lands. However, adjacent privately held lands continue to harbor melaleuca. Without incentives for private landowners to remove melaleuca, these contaminated lands will be a seed source for neighboring public lands for years to come. It is hoped that the newly funded region-wide TAME Melaleuca project will serve as a model for other species-based control programs. Policymakers are beginning to acknowledge that comprehensive invasive species management may require the expenditure of public monies on private lands or property tax breaks that provide a financial incentive for control.

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